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IN VITRO EVALUATION OF ANTIOXIDANT, ANTIBACTERIAL, CYTOTOXIC AND THROMBOLYTIC POTENTIAL OF *SYZYGIUM CUMINI* LEAF EXTRACT

Zarnab Anwar[1], Sabira Sultana[2*], Aisha Sethi[3], Naheed Akhtar[4], Rizwana Dilshad[5], Sara Saleem[6], Faheem Hadi[7], Dur E nayab[8], Remsha Khan[9], Farah Abid[10], Palwasha Khan[11], Nayla Javed[12], Farzana Parveen[13], Hafiz Saqib Zaka[14], Nadia Rai[15], Rabia Tasneem[16], Shehla Akbar[17]

[1,2]*Department of Eastern Medicine, Faculty of Medical Sciences, Government College University, Faisalabad - Pakistan
[3]Department of Pharmaceutics, Faculty of Pharmaceutical Sciences, Government College University, Faisalabad - Pakistan
[4]Department of Pharmacy, Faculty of Medical and Health Science, University of Poonch, Rawalakot, AJ&K - Pakistan
[5]Swedish College of Pharmacy and Allied Health Sciences, Rahim Yar Khan Campus - Pakistan
[6]Government Sadiq College Women University, Bahawalpur - Pakistan
[7]University College of Conventional Medicine, Faculty of Medicine and Allied Health Sciences, The Islamia University of Bahawalpur - Pakistan
[8]Department of Pharmacy, Faculty of Biological Sciences, Quaid i Azam University, Islamabad - Pakistan
[9]Department of Zoology Wildlife and Fisheries, Faculty of Sciences, University of Agriculture, Faisalabad - Pakistan
[10]Department of Pharmacy, The University of Lahore - Pakistan
[11,12,13,14,15,16]Faculty of Pharmacy, Department of Pharmaceutics, The Islamia University of Bahawalpur - Pakistan
[17]Department of Pharmacognosy, Faculty of Pharmacy, The Islamia University of Bahawalpur - Pakistan

***Correspondence Address:** Sabira Sultana
*Department of Eastern Medicine, Faculty of Medical Science, Government College University, Faisalabad - Pakistan; Email: drsabirachishti12@gmail.com

Abstract

Natural products from plants have been significant source of bioactive compounds with diverse pharmacological properties. *Syzygium cumini* commonly known as jamun, is a plant widely recognized for its traditional medicinal uses. This study is aimed to assess the in vitro evaluation of antioxidant, antibacterial, cytotoxic, and thrombolytic potential of *Syzygium cumini* leaf extract. The extracts were prepared using different solvents methanol, ethanol, and distilled water. The extracts of *Syzygium cumini* leaves were screened for total phenolic and flavonoid content using Folin-Ciocalteu method and aluminium chloride assay, respectively. The antioxidant activity was measured through DPPH scavenging assay. The antibacterial activity of the extracts was evaluated against bacterial strains using agar well diffusion method. The cytotoxic and thrombolytic potential was assessed through hemolytic assay and clot lysis method, respectively. Phytochemical analysis showed the presence of significant amounts of total phenolic (272.80 mgGAE/g) and flavonoid (383.684 µg catechin equivalents/ml) content in the *S.cumini* methanolic extract as compared to ethanolic and aqueous extract. The DPPH assay demonstrated highest % inhibition of 44.252% in *S.*

cumini ethanolic extract then methanolic and aqueous extract. Antibacterial investigation showed the zone of inhibition ranging from 11mm to 20mm as compared to standard ciprofloxacin. Moreover, the *S. cumini* extracts showed cytotoxic activity ranging from (3.715 to 6.727), highest activity shown by ethanolic extract. In the study of thrombolytic potential, different extracts of *S. cumini* revealed varying degrees of thrombolytic activity ranging from 14.191 to 19.552 %, ethanolic extract comparatively showed highest value. The findings suggest that *S. cumini* leaves has antioxidant, antibacterial, cytotoxic, and thrombolytic potential.

Key Words: *Syzygium cumini*, antibacterial, antioxidant, cytotoxic, thrombolytic potential

Introduction

Syzygium cumini is a n evergreen plant belongs to family Myrtaceae. Large trees that are grown all around for their edible fruits, such as the substances glucoside, gallic acid, cyanidin, tannins, anthocyanins, Vitamin C, petunidin, malvidin, and other nutrients are believed to be present in black plums. Unripe fruit juice is used to make vinegar, which is regarded as a diuretic, carminative, and stomachic. The fruits are utilized in the production of jams, jellies, and squash. The fruits have astringent properties [1]. The leaves have been utilized as a treatment in conventional medicine diabetes mellitus is prevalent worldwide. The leaves are also utilized to heal, strengthen, and maintain gums and teeth. stomach-aches, fever, gastropathy, leucorrhoea and constipation.

Different portions of the tree *Syzygium cumini* are abundant in flavonoids, carbohydrates, glycosides, sterols, alkaloids, and tannins etc. Phytochemicals support the body in different ways and protect against diseases. Non-nutritive plant compounds known as phytochemicals have anti-inflammatory and anti-disease capabilities [2].

Amino acids, cardiac glycosides, anthraquinone, alkaloids, tannins, phenols, flavonoids, terpenoids, saponins, phytosterols and terpenoids were found in all preparations of bark, leaves, stem, seeds, and fruit pulp of Jamun after ethanol extraction. The leaf extract lacked phytosterols and terpenoids. The seeds are calcium and protein rich. The seeds include gallic acid (1-2%), ellagic acid (19%), and tannins (19%). A glycoside, jamboline, starch, and myricyl alcohol are also detected in trace amounts (0.05%) in the unsaponified sand fraction along with a light-yellow essential oil. The extracted essential oils from freshly gathered leaves (which comprise 82% of the oil), fruits, stem, and seeds include sterculic acid, vernolic acid, cis-ocimeme, and trans-ocimeme. as well as -Pinene, camphene, -Pinene, myrcene, and limonene [3].

It is recommended to use fruit in case of menstrual abnormalities, obesity, vaginal discharge, and as cold infusion in cases of internal bleeding. The juice from the astringent bark is administered for dysentery, menorrhagia and chronic diarrhea. The bark is used to treat skin irritation and its decoction works well as a mouthwash and gargles to cure conditions like sore throats, stomatitis, and spongy gums. The bark is used to color fishnets, dye clothing, and tan leather. According to Ayurveda, its bark is good for the treatment of ulcers, bronchitis, sore throats, asthma, thirst, and dysentery as well as being astringent to the bowels [4]. The evergreen *Syzygium cumini* tree, also known as *Syzygium jambolana, Syzygium jambos* or *eugenia cumini* and found in Southeast Asia, Indian subcontinent and East Africa. In India, it is often referred to as Jamun. It is mostly used for producing fruit and for its wood. Antioxidant, antibacterial (particularly against the herpes virus), antifungal, antiviral, analgesic, anti-inflammatory, antihypertensive, antihyperglycemic, anticonvulsant, sedative, cytotoxic, spasmolytic, antihyperlipidemic, radioprotective, antipyretic, antiplaque, anti-arthritic, anti-fertility, hepatoprotective, allergic, anti-ulcer, neuro psycho pharmacology, antidiarrheal and nephroprotective properties [5]. The antidiabetic potential of *S. cumini* is most promising among all these physiological effects.

The objective of the research is to assess and analyse various pharmacological activities of the leaf extract of *Syzygium cumini*.

Material And Methodology

Collection and Identification of plant material

Syzygium cumini fresh leaves were gathered from the locally available mature plant in Faisalabad, Pakistan. The leaves were identified at the Botany Department, Government college university Faisalabad, Pakistan.

Drying of Leaves:

The plant leaves were rinsed in tap water to get rid of dirt. Then, the leaves were subjected to dry under shade for 6-7 days.

Grinding of leaves:

The leaves were grinded in an electric blender and the powder was stored in an airtight bag.

Extraction preparation:

The powder was soaked overnight with the solvent at 1:10 ratio. To prepare solutions three distinct solvents (methanol, ethanol, and water) were used 15gram /150mililiter of methanol, 15gram/150mililiter ethanol, and 15gram/150 milliliter of aqueous solutions, were prepared.
These solutions were rotated in a rotator shaker for 12 hours to mix all the constituents in the respective solvents.

Filtration:

All three solutions were filtered. At first, the solutions were filtered through the porcelain cloth and afterward, the filtrate was passed through the Whatman no 1 filter paper.

Drying of Extract:

The extracts were placed in a water bath at an appropriate temperature for drying. The ethanol and methanol extracts were died in 24 hours while the aqueous extract was dried in 4 days. Then the dried extracts were carefully removed from the microtiter plates. Sterilized blades were used to scratch the dried extracts, breaking them into smaller pieces. The dried and prepared extracts were stored in Eppendorf tubes at relatively low temperature for use in different experiments.

Antioxidant evaluation by DPPH, TPC, and TFC assay

DPPH scavenging activity

The antioxidant capacity of the sample was assessed using 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging assay, following the procedure outlined by [6]. In this assay, 3ml of the sample was mixed with 1ml of freshly prepared 0.004% DPPH in methanol solution. The combined solution was then kept in the dark for 30 minutes, and the absorbance was measured at 517nm. Lower absorbance reactions have a significant capacity to scavenge free radicals. As a control, ascorbic acid was used, and its antioxidant activity was also assessed. A solution without the plant extract served as the control. Most of the experiments were conducted in quadruplicate. The % of inhibition of DPPH radicals of the samples was calculated by the formula.

$$\text{DPPH Inhibition \%} = \frac{\text{Blank absorbance } (A_0) - \text{Sample absorbance}(A_1)}{\text{Blank absorbance } (A_0)} \times 100$$

Whereas,
A_0 = Absorbance of blank
A_1 = Absorbance of sample
The concentration of the sample having 50% inhibition (IC50) was determined by analyzing the graph inhibition percentage against sample concentration. These tests were conducted in quadruplets, with ascorbic acid as the positive control.

Determination of total phenolic contents (TPC)

The total phenolic content of the sample was determined using the Folin-Ciocalteu method as outlined by [7]. For the calibration curve, various concentrations of gallic acid (ranging from 0.01 to 0.10 mg/ml) were prepared in methanol. 1ml of each of these solutions was mixed with 4ml of 4% sodium carbonate and 5ml of diluted (ten-fold) Folin-Ciocalteu reagent. The absorbance was measured at 765 nm after 1 hour, and the calibration curve was constructed by plotting absorbance against concentration. For the sample extract, 1ml was mixed with the same reagent components mentioned above, and the absorbance of the resulting blue colored complex was measured at 765 nm after an hour [8]. All the measurements were conducted in quadruplets. The calculation was performed with reference to the standard (gallic acid), and the total content of phenolic compounds present in the plant extracts was determined in terms of Gallic acid equivalents (GAE) using the following formula.

T = C x V / M

Whereas,

T = total contents of phenolic compound in milligram GAE/gram of plant extract

C = the concentration of gallic acid calculated from calibration curve in milligram/milliliter

V = the volume of the extract in milliliters

M = the weight of the *Syzygium cumini* leaf extract in grams

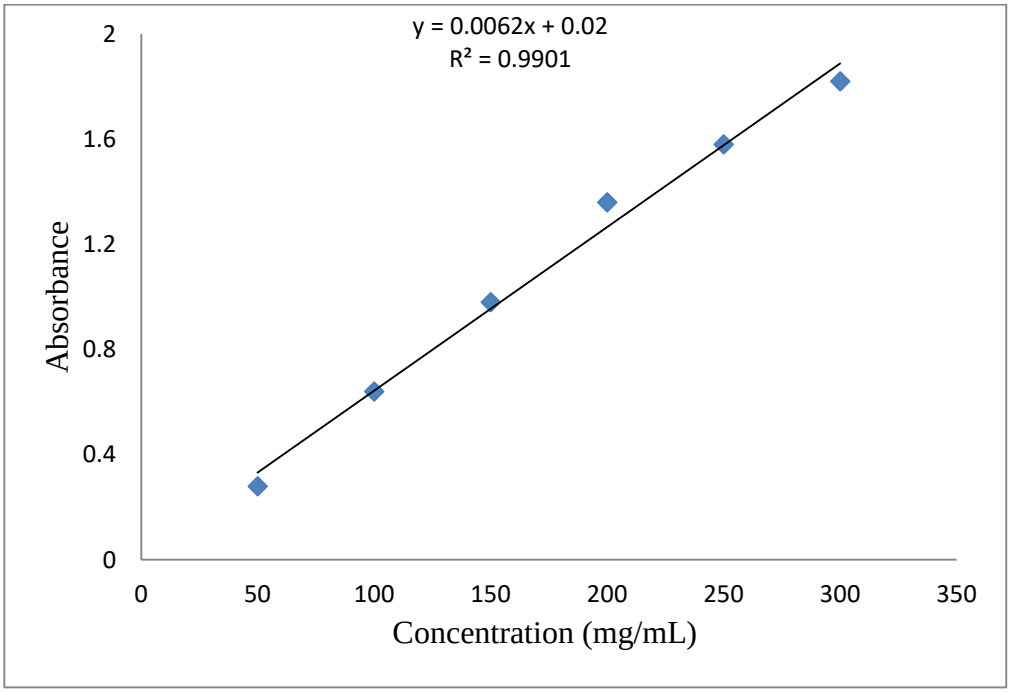

Figure 1: Standard curve of Gallic acid.

Total flavonoids contents (TFC)

The total flavonoid content of the sample was determined following the method outlined by Anwar et al. [9]. A 0.5 ml of the sample, 2ml of distilled water and 0.15ml of 5% $NaNO_2$ were combined and allowed to incubate for 6 minutes. Subsequently, the mixture was treated with 0.15ml of $AlCl_3$ 10% solution and incubated for an additional 6 minutes. Afterward, 4% NaOH solution was added. The volume of the reaction mixture was adjusted to 5ml by adding methanol and thoroughly mixed. The absorbance of the reaction mixture was measured at 510nm after 15 minutes of incubation.[10]. The TFC of the extracts were expressed as µg catechin equivalents per ml of the plant extract, based on a linear regression curve constructed using catechin as the standard.

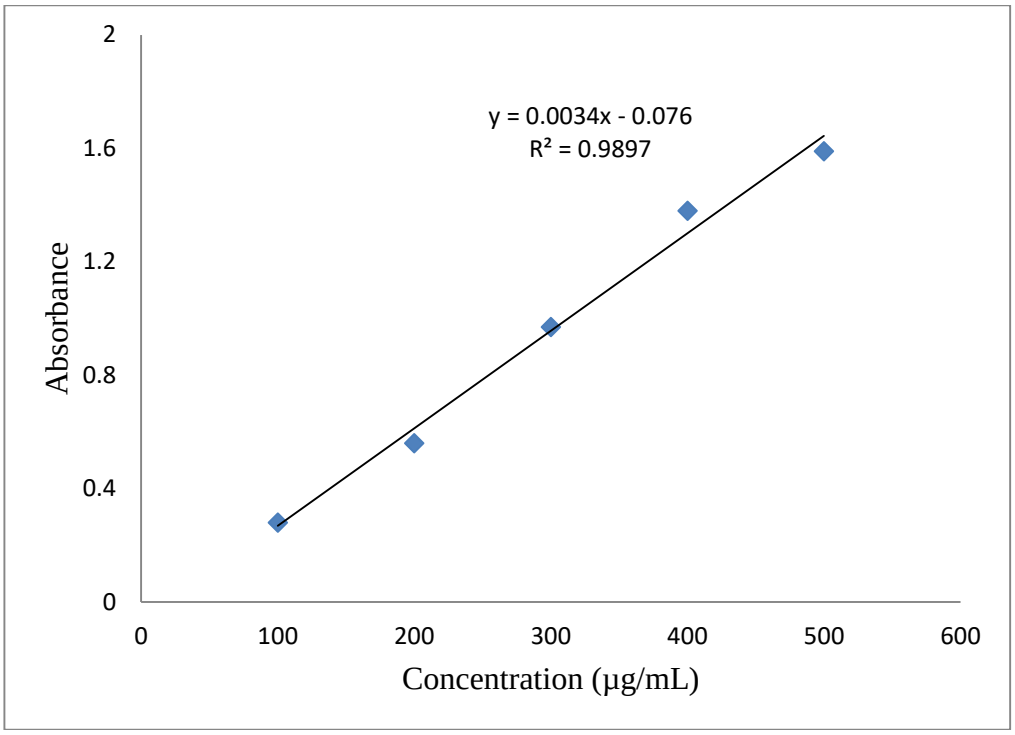

Figure 2: Standard curve of Catechin.

Antibacterial activity by agar well diffusion assay

The antibacterial activity of plant extracts against two bacterial strains, E. coli and S. aureus, was assessed using the agar-well diffusion method. Bacterial strains were cultured overnight at 37^0C on Nutrient agar (Oxoid UK). Specifically, a 100 µL suspension of the tested microorganisms, containing 10^7 colony forming units (CFU)/ml of bacterial strains, was spread on nutrient agar medium. To compare the sensitivity of the isolates or strains within the analyzed microbial species, Ciprofloxacin was employed as a positive control for bacteria. Subsequently, the plates were refrigerated at 4^0C for two hours and then incubated at 37^0C for 18 hours in the case of bacterial strains. The antibacterial activity was determined by measuring the zone of inhibition in millimeters with zone reader, for the organisms and comparing them to the control [11].

Cytotoxicity through hemolytic assay

Hemolytic Assay

The evaluation of hemolytic activity was conducted following the method employed by [12]. Three milliliters of freshly drawn heparinized bovine blood were collected from the Department of Eastern medicine, Government college university, Faisalabad, Pakistan. After centrifugation for 5 minutes at 100xg, the plasma was removed, and the cells were washed three times with 5ml of chilled 40C sterile isotonic Phosphate-Buffered Saline (PBS) with a pH of 7.4. For each assay, the erythrocytes were maintained at concentration of 108 cells per milliliter. In separate preparations, 100µl of each compound were mixed with human cells 108 cells/ml. The samples were then incubated for 35 minutes at 370C and agitated for 10 minutes. Immediately following incubation, the samples were placed on ice for 5 minutes and subsequently centrifuged for 5 minutes at 1000xg. From each tube, 100µl of supernatant was extracted and diluted 10 times with chilled 40C PBS. PBS was used as the negative control, while Triton X-100 (0.1% v/v) served as the positive control and subjected to the same procedure. The absorbance was measured at 576 nm using a Quant instrument (Bioteck, USA). The percentage of RBC lysis for each sample was then calculated.

% Hemolysis= Absorbance of sample – Absorbance of negative control/Absorbance of positive control x 100

Thrombolytic activity by clot lysis method

The evaluation of the thrombolytic activity of the extract was conducted using a method developed by Parsad with slight modifications [13]. Human blood samples were collected from healthy volunteers who had no history of anticoagulant therapy and oral contraceptives. A total of 7ml of venous blood were collected from 3 different healthy volunteers. The blood was then shifted into various pre-weighed sterilized microcentrifuge tubes, with each tube containing 1ml of blood. These tubes were subsequently incubated at 37^0C for a duration of 45 min. After the formation of clots, the serum was carefully removed from the tubes. The weight of each tube containing a clot was measured again to determine the clot weight (clot weight = weight of the clot containing tube – weight of the empty tube). Each tube containing a clot was labeled for further reference. The sample was thoroughly shaken on a vortex mixer after being dissolved in methanol. After vortex, the test samples were prepared at various concentrations (2,4,6,8 and 10 mg/ml, respectively). The suspensions were left overnight and then thoroughly mixed to remove the soluble supernatant. Subsequently, the suspensions were filtered using a 0.22-micron syringe filter. After filtration, 100µl of the methanolic extract was added to each labeled tube containing concentrations ranging from 2 to 10 mg/ml. simultaneously, 100µl of Streptokinase was added to one set of tubes containing the clots, serving as the positive thrombolytic control, while another set of tubes received 100µl of distilled water, which served as the negative thrombolytic control. Following these preparations, all the tubes were incubated for 90 minutes at 37^0C, and the clot lysis was observed (Prasad, Kashyap et al. 2006). Finally, the difference in weight measured before and after clot lysis was calculated as percentage of clot.

Statistical analysis

All quantitative assays were made in four repetitions. The differences were tested for statistical significance by one way ANOVA. The graphs were plotted using Microsoft EXCEL 2007.

Results And Discussion

The aim of this study was to assess the therapeutic potential of leaf extract from *Syzygium cumini*. It was found to have various bioactive compounds like polyphenols, flavonoids, and anthocyanins, which contribute to its antioxidant potential and enable it as a cytotoxic agent. Moreover, it showed an inhibitory effect against various Gram-negative and Gram-positive bacteria and was also believed to have a thrombolytic activity. The antioxidant activity of *Syzygium cumini* was checked by DPPH radical scavenging assay along with the estimation of total flavonoid and phenolic content. The antibacterial activity was evaluated by agar well diffusion method. The cytotoxic and thrombolytic potential was determined by using hemolytic analysis and the clot lysis method, respectively. The result of all these activities is mentioned here.

Antioxidant activity

Syzygium cumini leaf extract has compounds including polyphenols, triterpenoids, flavonoids, ellagic acid, anthocyanin and isoquercitin in different concentrations that are related to their physiological and biochemical properties [14]. Due to these components, it exhibits potent antioxidant activity. The free radical scavenging activity of a compound or molecule is its ability to scavenge free radicals. The free radical scavenging activity of *Syzygium cumini* leaf extract is assayed by using a synthetic free radical scavenger compound DPPH [15]. It is a stable free radical that has been extensively employed as a means of evaluating the antioxidant activity of substances capable of scavenging free radicals. DPPH produces violet or purple color in methanolic or ethanolic solution, but it fades to yellowish colour in the presence of an oxidant.

The %DPPH activity obtained from the SC leaf extract was in the range of 20-44%. Maximum antioxidant activity was shown by the ethanolic leaf extract i.e., 44.252%. Methanolic and aqueous extracts also have shown good results i.e., 42.116% and 42.523%, respectively.

Table 1 % DPPH activity of *Syzygium cumini* leaf extract

Plant extract	Concentrations ml	Blank Absorbance	Sample Absorbance	% inhibition of DPPH
***Syzygium cumini* Ethanolic extract**	50	0.983	0.674	31.434
	100	0.983	0.599	39.064
	200	0.983	0.57	42.014
	400	0.983	0.548	44.252
***Syzygium cumini* methanolic extract**	50	0.983	0.666	32.248
	100	0.983	0.596	39.369
	200	0.983	0.59	39.980
	400	0.983	0.569	42.116
***Syzygium cumini* aqueous extract**	50	0.983	0.777	20.956
	100	0.983	0.686	30.214
	200	0.983	0.627	36.216
	400	0.983	0.565	42.523

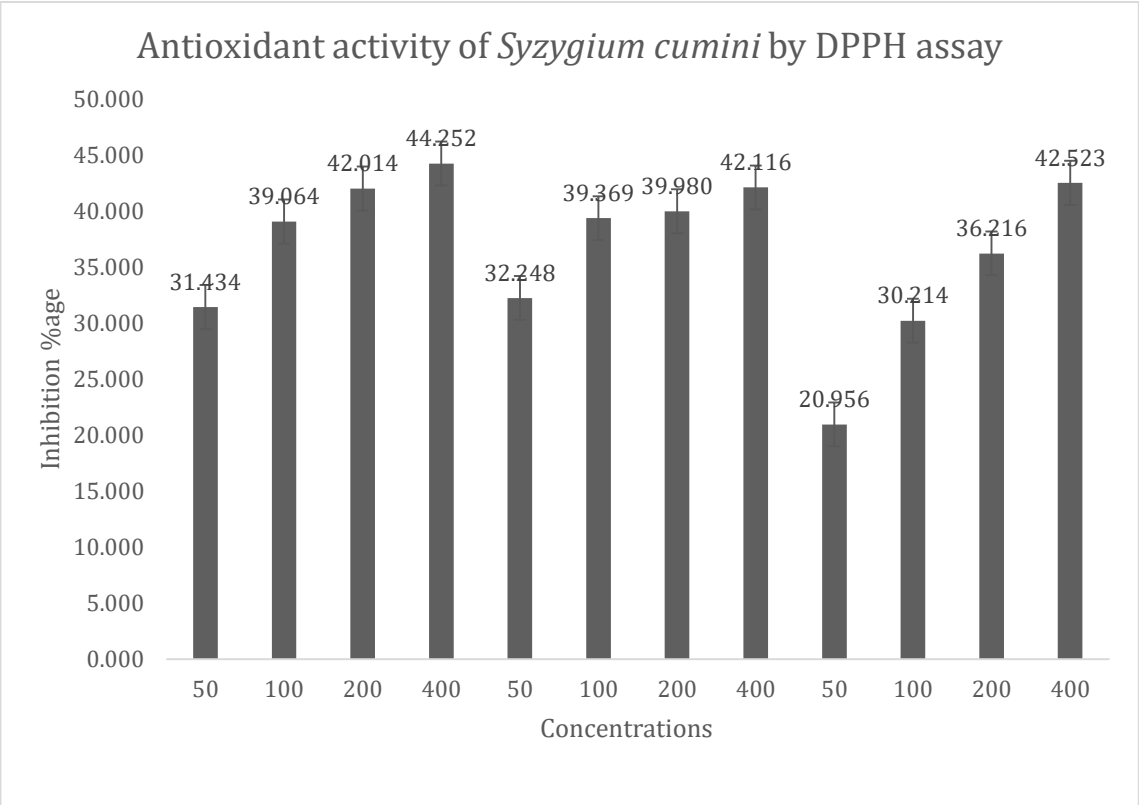

Fig 4.1 The % DPPH value of *Syzygium cumini* leaf extract

Total Phenolic Content

The total phenolic contents of the plant extracts were assessed by employing the Folin-Ciocalteu reagent and compared with a standard solution of gallic acid. The findings were then quantified and expressed as milligrams of gallic acid per gram of extract (Lamuela-Raventós 2018). Phenolic compounds in plants are associated to their antioxidant capabilities, as these compounds possess redox properties that allow them to function as potent reducing agents. Furthermore, it has been observed that the presence of phenolic compounds in a plants extract is directly influenced by the specific plant part used for extraction and the choice of solvent [16].

The total phenolic contents in the leaf extracts of *S. cumini* were measured, and the values ranged from 81.20 to 272.80mgGAE/g. Among the extracts, the methanolic extract exhibited the highest phenolic content at 272.80mgGAE/g followed by ethanol extract at 259.40mgGAE/g and the distilled water extract with a content of 81.20mgGAE/g.

Table 2 Total phenolic content of *Syzygium cumini* leaf extract

Plant extracts	Concentrations µl	mgGAE/g
Syzygium cumini **ethanolic extract**	50	171.00
	100	198.00
	200	233.60
	400	259.40
Syzygium cumini **methanolic extract**	50	160.40
	100	203.00
	200	271.60
	400	272.80
Syzygium cumini **aqueous Extract**	50	81.20
	100	150.00
	200	158.80
	400	194.40

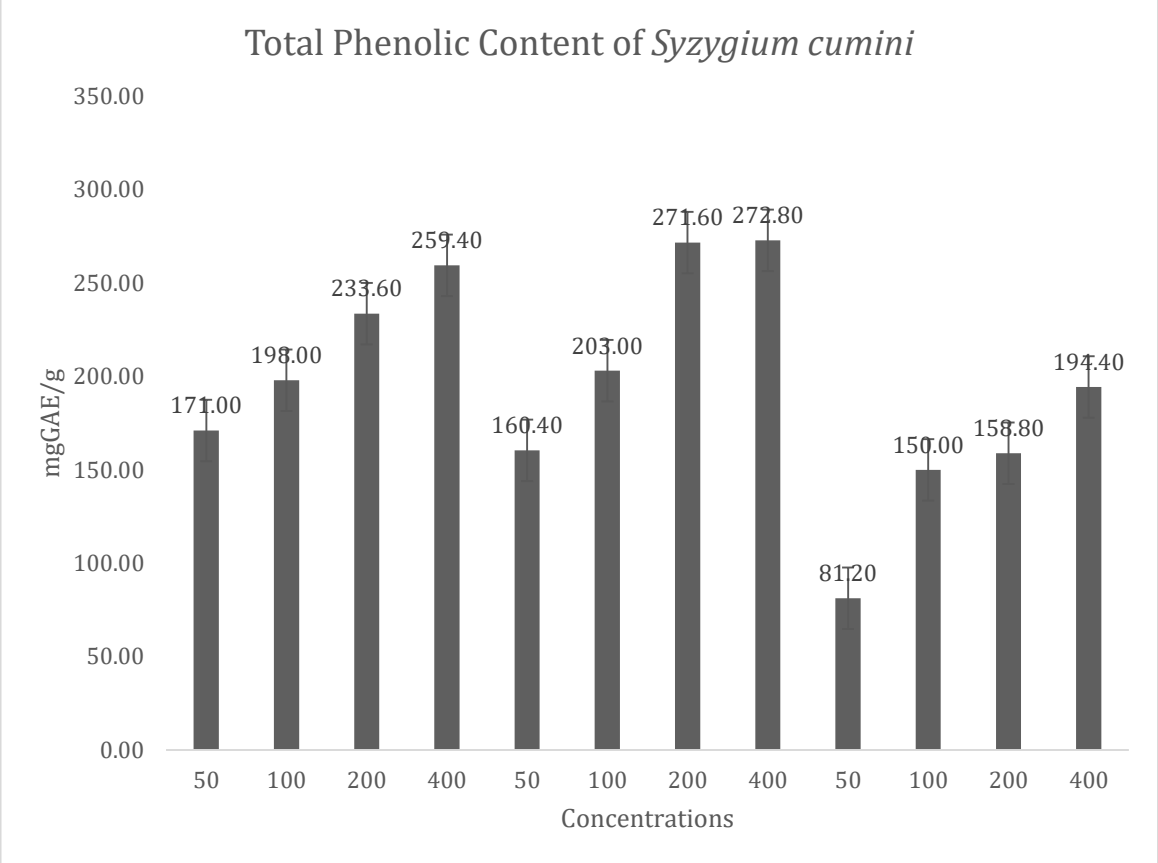

Figure 3 Total phenolic content of *Syzygium cumini* leaf extract

Total Flavonoid Content

The presence of flavonoids in a sample depends upon the solvent used for extraction. The difference in the flavonoid concentration may depend upon the plant material used, extraction solvent and chemical composition of the compound to be extracted [17].

The flavonoid content value of *Syzygium cumini* leaf extract ranges from 13.684 to 383.684µg catechin equivalents/mL. The highest value shown by methanolic extract 383.684 µg catechin equivalents/mL followed by ethanolic extract 242.895 µg catechin equivalents/mL and then 45.000 µg catechin equivalents/mL by aqueous extract.

Table 3 Total flavonoid content of *Syzygium cumini* leaf extract

Plant extracts	Concentrations µl	µg catechin equivalents/ml
***Syzygium cumini* ethanolic extract**	50	44.737
	100	57.105
	200	111.316
	400	242.895
***Syzygium cumini* methanolic extract**	50	89.211
	100	98.421
	200	187.105
	400	383.684
***Syzygium cumini* aqueous extract**	50	13.684
	100	18.947
	200	27.895
	400	45.000

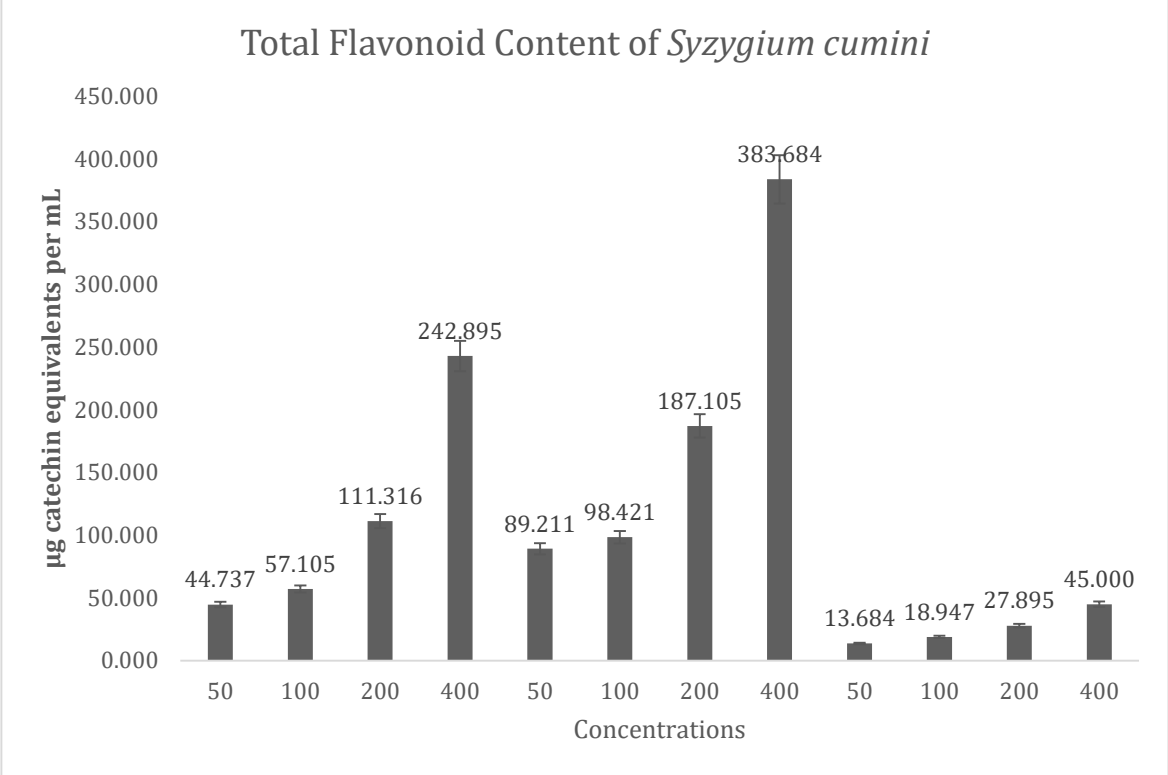

Fig 4 Total flavonoid content of *Syzygium cumini* leaf extract

Antibacterial activity

The antibacterial efficacy of leaf extracts from Syzygium cumini was examined against *S. aureus* a gram-positive bacterium, and *E. coli* a gram-negative bacterium. Ciprofloxacin was used as a standard antibiotic. Each extract inhibited the bacterial growth to an extent and that area was referred to as the zone of inhibition. This zone was measured in mm. The more antibacterial activity a substance exhibits, the larger will be the zone of inhibition.

In the case of *Staphylococcus aureus,* the maximum inhibitory activity was shown by distilled water extract i.e., 20mm although it was less than the control which inhibited an area of approximately 41mm. The ethanol extract produced an inhibitory zone of 17 mm, while the methanol extract resulted in a 12 mm inhibitory zone, the decreasing trend of the inhibitory zone of *Syzygium cumini* extract was observed as: Control(41mm) > Distilled water extract(20mm) > Ethanol(17mm) extract > Methanol extract (12mm).

Table 4. Zone of inhibition of Staphylococcus aureus by *Syzygium cumini* leaf extracts

Extracts	Zone of inhibition(mm)
***Syzygium cumini* ethanolic Extract**	17mm
***Syzygium cumini* methanolic Extract**	12mm
***Syzygium cumini* aqueous Extract**	20mm
Control (Ciprofloxacin)	41mm

Against *E. coli*, the control showed an inhibition zone of 37mm, and among the extracts maximum activity was shown by distilled water extract i.e., 17mm. The zone of inhibition seen by ethanol and methanol extract was 16mm and 11mm respectively. The values for the inhibition were in the order: Control (37mm) > Distilled water extract(17mm) > Ethanol extract(14mm) > Methanol extract (11mm).

Table 5. Zone of inhibition of *Escherichia coli* by *Syzygium cumini* leaf extracts

Extracts	Zone of inhibition(mm)
***Syzygium cumini* ethanolic extract**	16mm
***Syzygium cumini* methanolic extract**	11mm
***Syzygium cumini* aqueous extract**	17mm
Control (Ciprofloxacin)	37mm

Cytotoxicity through hemolytic assay

In vitro hemolytic activity performed on human erythrocytes on various concentrations extracts obtained from *Syzygium cumini*. Hemolytic assays were conducted because compounds with strong activity might not be suitable for pharmaceutical formulations if they exhibit hemolytic effects. Moreover, these results provide insights into the mechanism of cytotoxicity [18]. The prolonged use of high doses of antibiotics can damage the cell membrane. Therefore, the assessment of a drug's hemolytic potential is gaining attention among researchers.

The results revealed that the hemolytic activity of ethanol extract according to the dilutions 50µl, 100µl, 200µl, 400µl were 3.715, 4.953, 6.392, 6.727. The hemolytic activity of methanol extract according to the dilutions 50µl, 100µl, 200µl, 400µl were 4.150, 4.819, 5.020, 6.426. The hemolytic activity of aqueous extract with the dilutions 50µl, 100µl, 200µl, 400µl were 4.859, 5.288, 5.422, and 6.292. Hemolytic potential of all the extracts of *Syzygium cumini* have less than 10% hemolytic activity. The total hemolysis of *Syzygium cumini* leaf extract was determined using phosphate buffer saline as a negative control and Triton X-100 as a positive control.

Table 7. Hemolytic % of *Syzygium cumini* leaf extracts

Plant extracts	Concentra-tions µl	Sample Absorbance	Negative Control	Positive Control Absorbance	Final cytotoxic %
***Syzygium cumini* ethanolic extract**	50	0.194	0.083	2.988	3.715
	100	0.231	0.083	2.988	4.953
	200	0.274	0.083	2.988	6.392
	400	0.284	0.083	2.988	6.727
***Syzygium cumini* methanolic Extract**	50	0.207	0.083	2.988	4.150
	100	0.227	0.083	2.988	4.819
	200	0.233	0.083	2.988	5.020
	400	0.275	0.083	2.988	6.426
***Syzygium cumini* aqueous extract**	50	0.228	0.083	2.988	4.853
	100	0.241	0.083	2.988	5.288
	200	0.245	0.083	2.988	5.422
	400	0.271	0.083	2.988	6.292

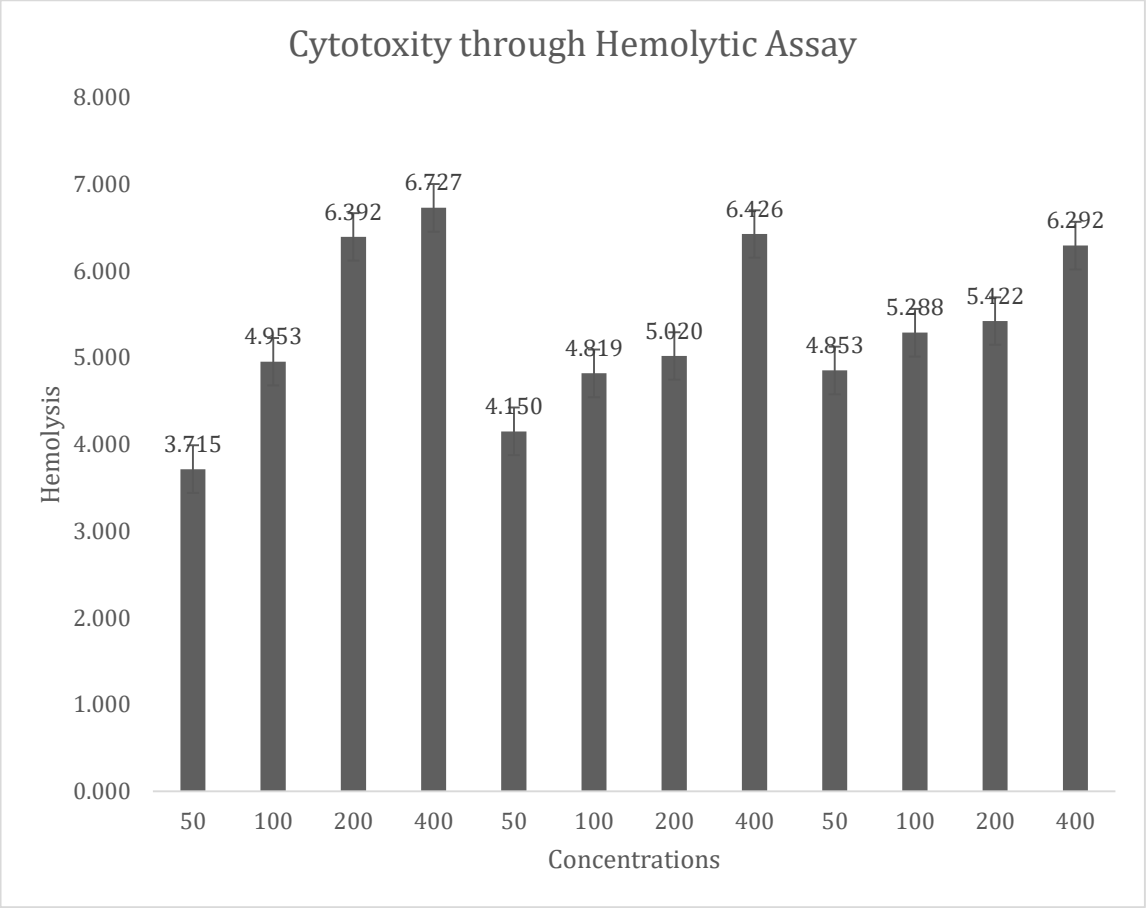

Fig 5 Hemolytic % of *Syzygium cumini* leaf extracts

Thrombolytic Activity

As part of the investigation into the development of cardio-protective drugs derived from natural sources, the thrombolytic activity of Syzygium cumini leaf extracts was evaluated. 100µl of distilled water and 100µl of Streptokinase were added as a negative and a positive control, respectively. In this study, the ethanolic extract exhibited highest thrombolytic activity by clot lysis of 19.552% followed by aqueous extract 19.089% and then by methanolic extract 17.125%. The values of all the extracts at different concentrations mentioned in the table below.

Table 8 % of lysis of *Syzygium cumini* leaf extracts

Plant extracts	Concentrations µl	Clot wt	wt of released clot	% of lysis
***Syzygium cumini* ethanolic extract**	50	489	79	16.155
	100	448	83	18.527
	200	462	89	19.264
	400	491	96	19.552
***Syzygium cumini* methanolic extract**	50	456	68	14.912
	100	464	72	15.517
	200	443	75	16.930
	400	473	81	17.125
***Syzygium cumini* aqueous extract**	50	451	64	14.191
	100	478	76	15.900
	200	457	82	17.943
	400	461	88	19.089

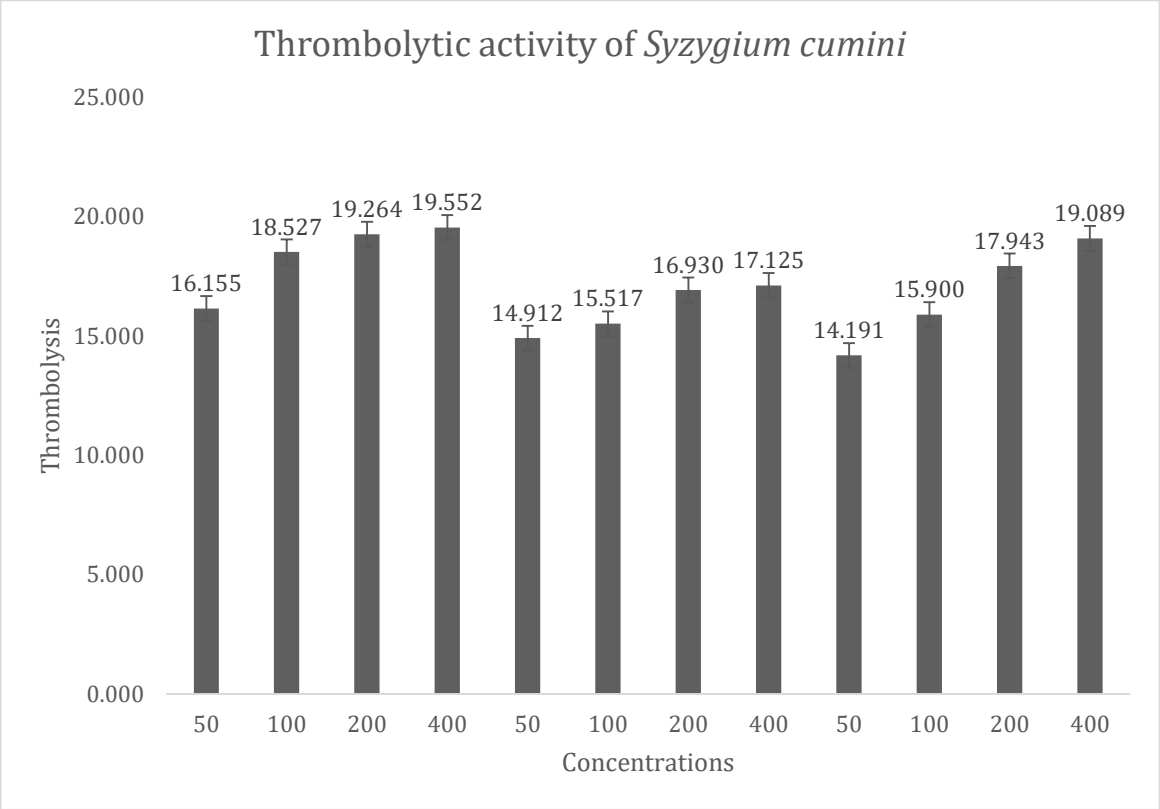

Figure 6. % of lysis of *Syzygium cumini* leaf extracts

Conclusion

This study provides comprehensive insights into the diverse biological activities of *Syzygium cumini* leaf extract. The results of the antibacterial assays indicate that *Syzygium cumini* leaf extract exhibits significant antibacterial activity against S. aureus and E. coli. This suggest that the extract contains bioactive compounds with the potential to inhibit bacterial growth. The cytotoxic effects of the leaf extract on various cell lines highlight its potential as a source of cytotoxic compounds. The significant thrombolytic activity suggests its potential in promoting the dissolution of blood clots. This property could hold substantial implications for cardiovascular health. The antioxidant activity observed in the extract shows its ability to scavenge free radicals and reduce oxidative stress. This property positions *Syzygium cumini* leaf extracts as a potential natural antioxidant source for managing oxidative stress related disorders. The collective findings of this study highlight the diverse bioactive compounds present in *Syzygium cumini* leaf extract which contribute to its antibacterial, cytotoxic, thrombolytic and antioxidant activities. The research contributes to the understanding of its potential therapeutic applications, warranting further investigations for the development of novel therapeutic agents or nutraceuticals. However, the results also highlight the need of further studies, including in vivo experiments, to validate the observed effects and to utilize them into practical applications for human health.

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